Technical Report No. 6224

FABRICATION OF BURN DRESSINGS FROM FOAMED ACRYLATE-AMIDE ELASTOMERS

Work by: Carl A. Nielson
Gerry N. Wixson

Reported by: Gerry N. Wixson

November 1962

U. S. ARMY PROSTHETICS RESEARCH LABORATORY
WALTER REED ARMY MEDICAL CENTER
WASHINGTON 12, D. C.

T. R. No. 6224*

Project: 6X59-01-001-04

Date Started: April 1962

Date Completed: July 1962

Recommend Approval:

Fred Leonard

Scientific Director

Approved:

John Batchelor, Lt Col, MC

Director

*Qualified requesters may obtain copies of this report from ASTIA.

ABSTRACT

This report describes research leading to the fabrication of a burn dressing from a foamed acrylate-amide elastomer for Brooke Army Medical Center, Fort Sam Houston, Texas.

Factors involved in the preparation of the elastomer, foam, and burn dressing are discussed. A method for determining the porosity of foamed acrylate-amide elastomers is described.

I. Introduction

The apparent tissue acceptance of the acrylate-amide terpolymer elastomers in a variety of internal body prostheses prompted the thought that the material might find application as a bandaging material for burns.

This possible application was discussed with Lt. Col. J. Moncreif, MC, Commanding, U. S. Army Surgical Research Unit, Brooke Army Medical Center, Fort Sam Houston, Texas and desirable film characteristics for this application were outlined.

They were as follows:

1. Thickness .0120 - .0160 in. (3.0 - 4.0 mm)
2. Elastic Stretch - 50-75% of its length before tearing
3. Wettable - having a water throughput 2.0 - 6.5 Kg/cm^2/hr at 38 cm of water pressure
4. Color - white
5. Resistance to tear - good
6. Surface Structure
   (a) Outside surface - a microporous layer with pore size ranging from 20 - 25 microns

   (b) Wound contact surface - very porous and irregular surface

Evaluation of such foams on a fairly large number of laboratory animals by the U. S. Army Surgical Research Unit indicated that the acrylate foam had the most promise of any of the materials tested as a skin prosthesis. Good tissue ingrowth was obtained within three days of placing it on the back of a rat. The pores of the foam filled with serum during the first day and caused the wound itself to remain moist. The serum was a disadvantage, however, because it became colonized with bacteria within the first three days. The evaluation group, however, indicated that they may be able to use the foam as a means of treating the serum that collects and thus inhibit the bacteria.

The purpose of this report is to discuss the prepartion and uniformity, based on a porosity (water throughput) evaluation of the original foam acrylic elastomer burn dressing material submitted for surgical evaluation.

II. Preparation of Elastomers

The 90/7.5/2.5 butyl acrylate-methyl methacrylate-methacrylamide terpolymer elastomer latex was selected for this application. Foam elastomers were fabricated from elastomer latices synthesized at the U. S. Army Prosthetics Research Laboratory and the Borden Company. In this report foams fabricated from the USAPRL elastomer latex will be referred to as Composite A Foams, and foams fabricated from the Borden Company elastomers latex will be referred to as Composite B Foams.

The latices were compounded as follows:

COMPOUNDED LATEX	PARTS BY WEIGHT
Latex (30-40% solids)	100
Polyethyl methacrylate 1/ latex (40-50% solids)	37
Formaldehyde (37% solids)	1.735

III. Preparation of Burn Dressings

Composite A - The foam formulation selected was as follows:

Compounded Latex	200 g.
Citric Acid (in solution)	5 ml.
Ammonia (concentrated)	15 drops (using standard medicine drop)
Sodium Polyacrylate (50% solution) 2/	5 ml.
Sodium Fluorosilicate (50% emulsion)	2 g.

1/ Rohm & Haas Co., Philadelphia, Pennsylvania

2/ Nopco Co., Modicol VD, Newark, New jersey

The latex, citric acid, ammonia, and sodium polyacrylate were added to a 1,000 ml. beaker and blended with a flat paddle stirrer. The mixture was then transferred to the bowl of a Sunbeam Mixmaster and mixed at high and intermediate speeds unitl a homogenous mass of 4½ times the original volume was obtained. The sodium fluorosilicate was added and mixing was continued for 30 seconds at half speed. The resulting foam was poured over a setting bed consisting of two layers of dacron coth and spread with a 3/8 inch gap polyethylene blade. After setting for 16-24 hours at 80-100% relative humidity at 25°C, the foams were leached in a boiling water bath for 48-72 hours, immersed in a 3-5% solution of formaldehyde for 2 hours at 115°C. and autoclaved at 260°F. for 30 minutes. After processing, the outside layer of dacron cloth was stripped from each sample.

Composite B - Burn dressing samples were prepared using the same procedure as for Composite A, but the following formulation was used:

Compounded Latex	200 g.
Citric Acid (in solution)	5 ml.
Ammonia (concentrated)	25 drops
Sodium polyacrylate (50% solution)	6 ml.
Sodium Fluorosilicate (50% emulsion)	2 g.

After processing, the outside layer of dacron cloth was removed from 70% of the samples and both layers of cloth were removed from the remaining 30%.

IV. Physical Evaluation

The physical properties of porosity, density, and thickness were determined for each foam sample submitted for evaluation. T ble I summarizes the results.

The "cloth on" average porosity and average thickness values are an average of measurements made on two test samples from each foam which are still reinforced with one layer of dacron cloth.

With the exception of B 1, 8, 9, the "cloth off" average porosity, density, and average thickness values are the measurements made on one test sample from each foam which has had both layers of dacron cloth removed. The "cloth off" average porosity, density, and average thickness values for samples B 1, 8, and 9 are the average of three test samples from each foam which have had both layers of dacron cloth removed.

V. Samples for Surgical Evaluation

Nine samples of Composite A foams with one layer of dacron cloth reinforcement and ten samples of Composite B foams, seven with one layer of dacron cloth reinforcement, and three with no reinforcement were sent to Brooke Army Medical Center, Fort Sam Houston, Texas for surgical evaluation as burn dressings.

VI. Theory and Discussion

It has been shown that the porosity properties of epoxy porous laminates may be defined by the standard filtration equation.[3] It was decided to apply this equation to delineate the porosity of burn dressing films.

The standard filtration equation is:

$$\left(\frac{dV}{d\theta}\right)\frac{1}{A} = \frac{\Delta P}{MR} + K \qquad \text{Eq. 1} \quad [4]$$

where: v = the volume of water (cm^3) collected up to time θ (sec.)
A = the cross section of the test sample (cm^2)
M = viscosity of the test fluid (centipoise)
ΔP = pressure drop across the laminate (cm of H_2O)
R = resistance of the foam to water flow

Plots of porosity vs. pressure difference on a log-log plot (figs. 1, 2, 3, and 4) produced straight lines with varying slopes indicating no compressibility variation within the limits of the experiment but a variable resistance.

3/ Hill, J. T., DeVries, E., Leonard, F., SPE, <u>16</u>, No. 9, Sept. 1960.

4/ Perry, J. H., Chem. Engineering Handbook, Ed. 2, McGraw-Hill Book Co., Subject: Filtration, page 1653, 1941.

The resistance (R) determined by Equation 2 is presented in Table II. Results show that R is defined by,

$$R = \frac{1}{m} \quad \frac{1}{\text{slope}} \qquad \text{Eq. 2}$$

and is variable.

It is possible to obtain a variable resistance (R) from a foam sampling made up of foams of similar cell structure if the thickness and size of the pores are different. Thus to determine the uniformity of the foams in a smapling, a description of cell structure is desirable. The Koenzy Filtration Equation lends a method for determining cell structure of a material which conforms to the filtration equations. Pore size determined by the Koenzy Equation would be a description of the average size pore of that sample. Using this measurement for evaluating the foam elastomer burn dressing ("cloth off" sampling) one must consider that different porosity levels exist on the two surfaces of the material, thus the measured value would not describe any one surface of a foam but would be a relative value forming a basis for evaluating the uniformity of a foam composite. For the purposes of this report the pore size determined by the Koenzy Equation for "cloth off" sample will be defined as the "Relative Average Pore Size."

The Relative Pore Size is related to the free volume and surface area of a foam by Equation (3). The surface area

$$Dre = \frac{4B}{So\,(1-B)} \qquad \text{Eq. 3} \quad 5/$$

where Dre = The Relative Average Pore Size (cm).

B = Volume of voids per unit volume of foam.

So = Surface area of a foam per unit solid volume. (cm)
So - can be determined from the Koenzy Equation when arranged as Equation 4.

$$So^2 = \frac{A\,\Delta P\,E'}{L\,r\,(\frac{dV}{d\theta})} \quad \frac{E^3}{(1-E)^2} \qquad \text{Eq. 4} \quad 6/$$

5/ Badger & Branchero, Introduction to Chem. Engrg., McGraw-Hill Book Co., 1955, Page 579.

6/ Ibid, Page 579

where

So = Surface area per unit solid volume (cm^1)

A = Cross Section of the test sample (cm^2)

M = Viscosity of the test fluid (centipoise) x 10^{-2}

L = Thickness of the test sample (cm)

ΔP = Pressure drop across the sample ($dynes/cm^2$)

F^3 = Flow rate of the test fluid (cm^3/sec)

B = Volume of voids per volume of foam

The volume of voids per unit volume of foam (B) can be determined from the densities of the foam and solid elastomer. If df is the density of the foam, de is the density of the elastomer, and wu is weight of a unit volume of foam then the difference wu/df-wu/de would equal (B).

The Relative Average Pore Size (Dre) was determined for the "cloth off" samples of the Borden and USAPRL Burn Dressing Composites using Equation 5 and 6 and is presented in Table III. In evaluating the USAPRL Composite 6 out of 9 foams have Dre's in the range of 40 ° 50 microns with the other foams not varying 5.0 microns from this range. For the Borden Company Composite 7 out of 10 foams have Dre's ranging from 37 - 47 microns with the other foams not varying 7.0 microns from this range.

In conclusion the water throughput porosity evaluation of the original foam acrylate elastomer burn dressing samples presented for field evaluation has demonstrated that a replicable foam burn dressing can be made by following the procedure set down in this report.

Summary

Methods for the preparation and laboratory evaluation of acrylate terpolymer foam elastomers to be used in burn dressing application have been presented. Samples of these materials have been submitted to Brooke Army Medical Center, Surgical Research Unit for surgical evaluation.

TABLE I

Measured Physical Properties (11)

Sample No. Pressure (H_2O)*	Average Porosity ($cc/cm^2/sec$) "cloth on" 39 cm	64 cm	38 cm	"cloth off" 39 cm	64 cm	38 cm	Density (g/cm^3) "cloth off"	Average Thickness (cm) "cloth on"	"cloth off"
A -1	0.485	0.340	0.190	0.552	0.395	0.222	0.224	0.57	0.48
A -2	0.641	0.450	0.252	0.605	0.535	0.274	0.252	0.38	0.33
A -3	0.800	0.649	0.427	1.540	1.031	0.674	0.223	0.33	0.30
A -4	0.866	0.652	0.430	1.626	1.051	0.707	0.244	0.37	0.30
A -5	1.257	1.017	0.697	1.520	1.192	0.764	0.201	0.41	0.33
A -6	1.470	1.065	0.649	1.760	1.251	0.803	0.310	0.28	0.23
A -7	0.925	0.553	0.330	1.035	0.785	0.445	0.247	0.40	0.31
A -8	0.686	0.470	0.238	0.980	0.741	0.393	0.256	0.38	0.31
A -9	0.865	0.627	0.346	2.260	1.370	0.930	0.332	0.30	0.19
B -1	-	-	-	2.447	1.542	1.105	0.237	-	0.26
B -2	0.442	0.270	0.119	0.637	0.417	0.195	0.309	0.42	0.33
B -3	0.686	0.495	0.288	0.842	0.558	0.351	0.242	0.46	0.42
B -4	0.637	0.458	0.269	1.365	0.962	0.600	0.239	0.44	0.34
B -5	0.371	0.627	0.403	1.097	0.745	0.452	0.246	0.34	0.30
B -6	0.532	0.402	0.228	0.965	0.630	0.321	0.254	0.46	0.41
B -7	0.519	0.371	0.210	1.310	0.746	0.531	0.240	0.36	0.28
B -8	0.472	0.233	0.130	0.759	0.504	0.255	0.231	0.42	0.37
B -9	-	-	-	1.360	0.862	0.483	0.247	-	0.30
B -10	-	-	-	0.975	0.648	0.267	0.225	-	0.40

* Porosities are given for pressures of 39, 64, 38 cm of H_2O in each case.

The specific gravities for the solid film of the elastomer foam mixture are as follows:

Composite A - 1.060 g/cm^3

Composite B - 0.945 g/cm^3

TABLE II

Water Throughput Resistance

Sample	R ($cm^4/dyne^2$) "cloth off"	R ($cm^4/dyne^2$) "cloth on"
A -1	0.000278	0.000320
-2	0.000254	0.000378
-3	0.000157	0.000360
-4	0.000129	0.000321
-5	0.000193	0.000218
-6	0.000147	0.000193
-7	0.000218	0.000225
-8	0.000244	0.000320
-9	0.000111	0.000262

Sample	R ($cm^4/dyne^2$) "cloth off"	R ($cm^4/dyne^2$) "cloth on"
B -1	0.000108	- - -
-2	0.000292	0.000424
-3	0.000284	0.000340
-4	0.000176	0.000348
-5	0.000230	0.000304
-6	0.000174	0.000487
-7	0.000143	0.000487
-8	0.000327	0.000500
-9	0.000163	- - -
-10	0.000154	- - -

TABLE III

Relative Average Pore Size
Dre

Sample	B	Dre (Microns) Pressure (H_2O)* 89 cm	64 cm	38 cm
A 1	.786	35.4	35.3	34.4
A 2	.759	35.9	38.7	35.8
A 3	.787	45.6	43.3	45.5
A 4	.767	48.7	46.2	49.3
A 5	.809	49.5	51.5	53.5
A 6	.703	46.4	46.4	48.0
A 7	.764	43.7	43.7	42.7
A 8	.755	38.1	39.0	37.0
A 9	.683	50.3	46.1	49.5
B 1	.751	52.0	48.4	53.0
B 2	.674	30.0	28.7	28.0
B 3	.744	37.6	37.4	38.6
B 4	.747	47.5	47.1	48.4
B 5	.740	38.9	37.8	38.2
B 6	.731	44.4	42.4	40.0
B 7	.746	37.1	33.1	36.4
B 8	.755	37.7	36.2	33.2
B 9	.738	46.5	42.6	41.0
B 10	.762	44.0	42.0	35.5

* Relative Average Pore Size (Dre) was calculated for water throughput porosities measured at pressures of 89, 64, 38 cm. of water for each sample.

Figure 1

$\log \frac{dv}{dc}$ vs. $\log \Delta P$

Composite A "Cloth off"

Sampling

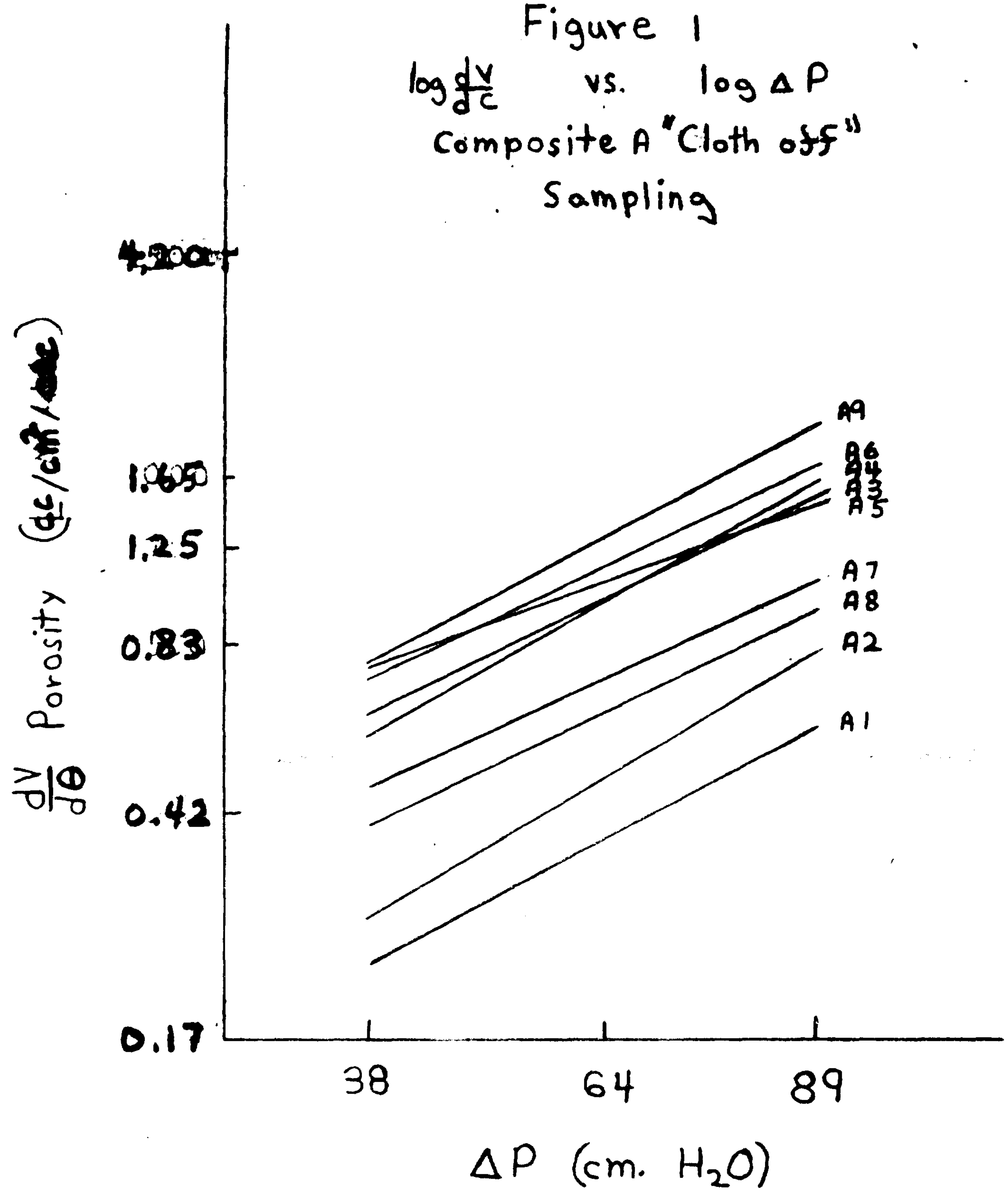


Figure 2

$\log \frac{dV}{dC}$ vs $\log \Delta P$

Composite B "Cloth off"

Sampling

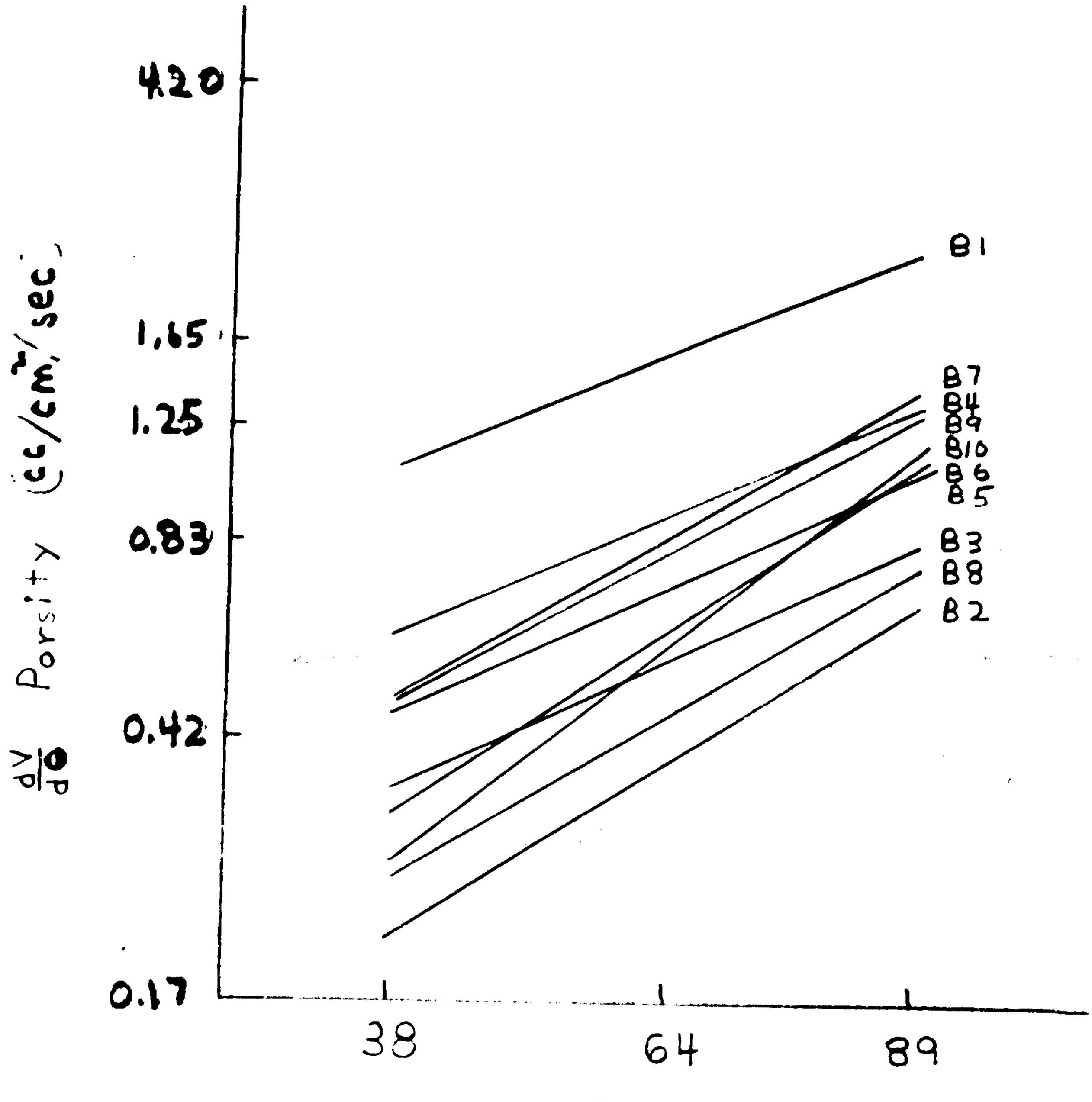


Figure 3

$\log \frac{dV}{dC}$ vs. $\log \Delta P$

Composite A "Cloth on" Sampling

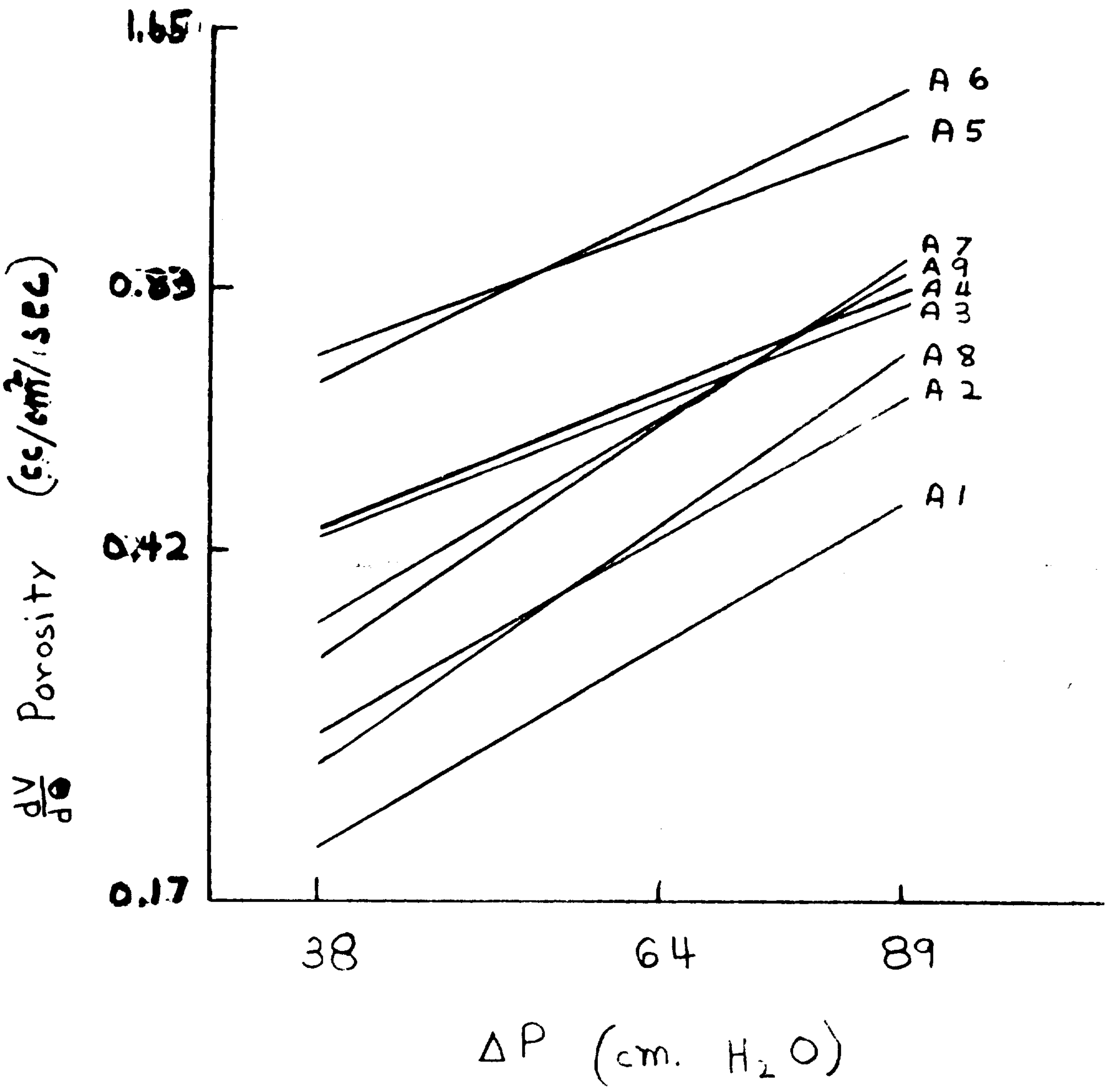
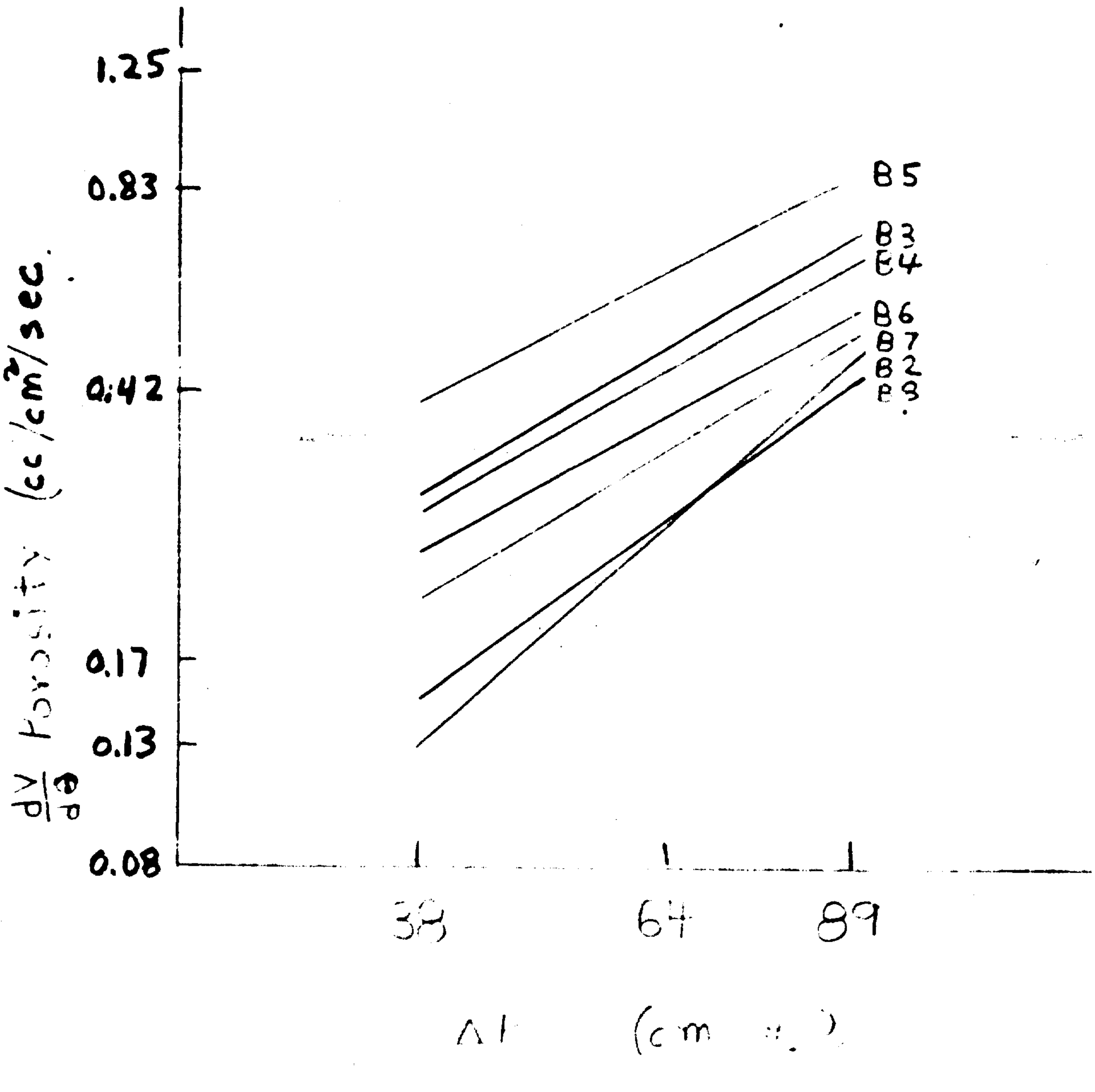


Figure 4

$\log \frac{dv}{dC}$ vs. $\log \Delta P$

Composite B "Cloth on" Sampling



ABSTRACT CARD

TITLE: Fabrication of Burn Dressings from Foamed Acrylate-Amide Elastomers

AUTHOR (S): Carl A. Nielson, Gerry N. Wixson

AGENCY: USA Prosthetics Res. Lab. Walter Reed AMC, Washington 12, D. C.

TECH. RPT. 6224 UNCLASSIFIED

Project 6X59-01-001-04

AD __________ # ______

1. Burn Dressing
2. Elastomer Porosity

XX
XX

ABSTRACT: This report describes research leading to the fabrication of a burn dressing from a foamed acrylate-amide elastomer for Brooke Army Medical Center, Fort Sam Houston, Texas.

Factors involved in the preparation of the elastomer, foam, and burn dressing are discussed. A method for determining the porosity of foamed acrylate-amide elastomers is described.

WRAMC FORM 0183 (ONE TIME) 15 MAY 1961

ABSTRACT CARD

TITLE: Fabrication of Burn Dressings from Foamed Acrylate-Amide Elastomers

AUTHOR (S): Carl A. Nielson, Gerry N. Wixson

AGENCY: USA Prosthetics Res. Lab. Walter Reed AMC, Washington 12, D. C.

TECH. RPT. 6224 UNCLASSIFIED

Project 6X59-01-001-04

AD __________ # ______

1. Burn Dressing
2. Elastomer Porosity

XX
XX

ABSTRACT: This report describes research leading to the fabrication of a burn dressing from a foamed acrylate-amide elastomer for Brooke Army Medical Center, Fort Sam Houston, Texas.

Factors involved in the preparation of the elastomer, foam, and burn dressing are discussed. A method for determining the porosity of foamed acrylate-amide elastomers is described.

WRAMC FORM 0183 (ONE TIME) 15 MAY 1961

ABSTRACT CARD

TITLE: Fabrication of Burn Dressings from Foamed Acrylate-Amide Elastomers

AUTHOR (S): Carl A. Nielson, Gerry N. Wixson

AGENCY: USA Prosthetics Res. Lab. Walter Reed AMC, Washington 12, D. C.

TECH. RPT. 6224 UNCLASSIFIED

Project 6X59-01-001-04

AD __________ # ______

1. Burn Dressing
2. Elastomer Porosity

XX
XX

ABSTRACT: This report describes research leading to the fabrication of a burn dressing from a foamed acrylate-amide elastomer for Brooke Army Medical Center, Fort Sam Houston, Texas.

Factors involved in the preparation of the elastomer, foam, and burn dressing are discussed. A method for determining the porosity of foamed acrylate-amide elastomers is described.

WRAMC FORM 0183 (ONE TIME) 15 MAY 1961

ABSTRACT CARD

TITLE: Fabrication of Burn Dressings from Foamed Acrylate-Amide Elastomers

AUTHOR (S): Carl A. Nielson, Gerry N. Wixson

AGENCY: USA Prosthetics Res. Lab. Walter Reed AMC, Washington 12, D. C.

TECH. RPT. 6224 UNCLASSIFIED

Project 6X59-01-001-04

AD __________ # ______

1. Burn Dressing
2. Elastomer Porosity

XX
XX

ABSTRACT: This report describes research leading to the fabrication of a burn dressing from a foamed acrylate-amide elastomer for Brooke Army Medical Center, Fort Sam Houston, Texas.

Factors involved in the preparation of the elastomer, foam, and burn dressing are discussed. A method for determining the porosity of foamed acrylate-amide elastomers is described.

WRAMC FORM 0183 (ONE TIME) 15 MAY 1961

ABSTRACT CARD

TITLE: Fabrication of Burn Dressings from Foamed Acrylate-Amide Elastomers

AUTHOR (S): Carl A. Nielson, Gerry N. Wixson

AGENCY: USA Prosthetics Res. Lab. Walter Reed AMC, Washington 12, D. C.

TECH. RPT. 6224 UNCLASSIFIED

Project 6X59-01-001-04

ABSTRACT: This report describes research leading to the fabrication of a burn dressing from a foamed acrylate-amide elastomer for Brooke Army Medical Center, Fort Sam Houston, Texas.

Factors involved in the preparation of the elastomer, foam, and burn dressing are discussed. A method for determining the porosity of foamed acrylate-amide elastomers is described.

WRAMC FORM 0183 (ONE TIME) 15 MAY 1961

AD ________ # ____

1. Burn Dressing
2. Elastomer Porosity

XX

XX

ABSTRACT CARD

TITLE: Fabrication of Burn Dressings from Foamed Acrylate-Amide Elastomers

AUTHOR (S): Carl A. Nielson, Gerry N. Wixson

AGENCY: USA Prosthetics Res. Lab. Walter Reed AMC, Washington 12, D. C.

TECH. RPT. 6224 UNCLASSIFIED

Project 6X59-01-001-04

ABSTRACT: This report describes research leading to the fabrication of a burn dressing from a foamed acrylate-amide elastomer for Brooke Army Medical Center, Fort Sam Houston, Texas.

Factors involved in the preparation of the elastomer, foam, and burn dressing are discussed. A method for determining the porosity of foamed acrylate-amide elastomers is described.

WRAMC FORM 0183 (ONE TIME) 15 MAY 1961

AD ________ # ____

1. Burn Dressing
2. Elastomer Porosity

XX

XX

ABSTRACT CARD

TITLE: Fabrication of Burn Dressings from Foamed Acrylate-Amide Elastomers

AUTHOR (S): Carl A. Nielson, Gerry N. Wixson

AGENCY: USA Prosthetics Res. Lab. Walter Reed AMC, Washington 12, D. C.

TECH. RPT. 6224 UNCLASSIFIED

Project 6X59-01-001-04

ABSTRACT: This report describes research leading to the fabrication of a burn dressing from a foamed acrylate-amide elastomer for Brooke Army Medical Center, Fort Sam Houston, Texas.

Factors involved in the preparation of the elastomer, foam, and burn dressing are discussed. A method for determining the porosity of foamed acrylate-amide elastomers is described.

WRAMC FORM 0183 (ONE TIME) 15 MAY 1961

AD ________ # ____

1. Burn Dressing
2. Elastomer Porosity

XX

XX

ABSTRACT CARD

TITLE: Fabrication of Burn Dressings from Foamed Acrylate-Amide Elastomers

AUTHOR (S): Carl A. Nielson, Gerry N. Wixson

AGENCY: USA Prosthetics Res. Lab. Walter Reed AMC, Washington 12, D. C.

TECH. RPT. 6224 UNCLASSIFIED

Project 6X59-01-001-04

ABSTRACT: This report describes research leading to the fabrication of a burn dressing from a foamed acrylate-amide elastomer for Brooke Army Medical Center, Fort Sam Houston, Texas.

Factors involved in the preparation of the elastomer, foam, and burn dressing are discussed. A method for determining the porosity of foamed acrylate-amide elastomers is described.

WRAMC FORM 0183 (ONE TIME) 15 MAY 1961

AD ________ # ____

1. Burn Dressing
2. Elastomer Porosity

XX

XX